NCRF R&D Program and Plans

Bob Rimmer, Derun Li, Tony Ladran, LBNL,
Al Moretti, FNAL, Jim Norem, ANL.

NCRF R&D Program and Plans

Outline

FY01 results and progress

805 MHz open cell cavity
- Lab G results:
- Conditioning, Dark current, X-rays and breakdown

805 MHz closed cavity
- Manufacturing snafu
- Pre-stress measurements

201.25 MHz cavity
- study-II/IMICE geometry, conceptual design, "foils" and grids

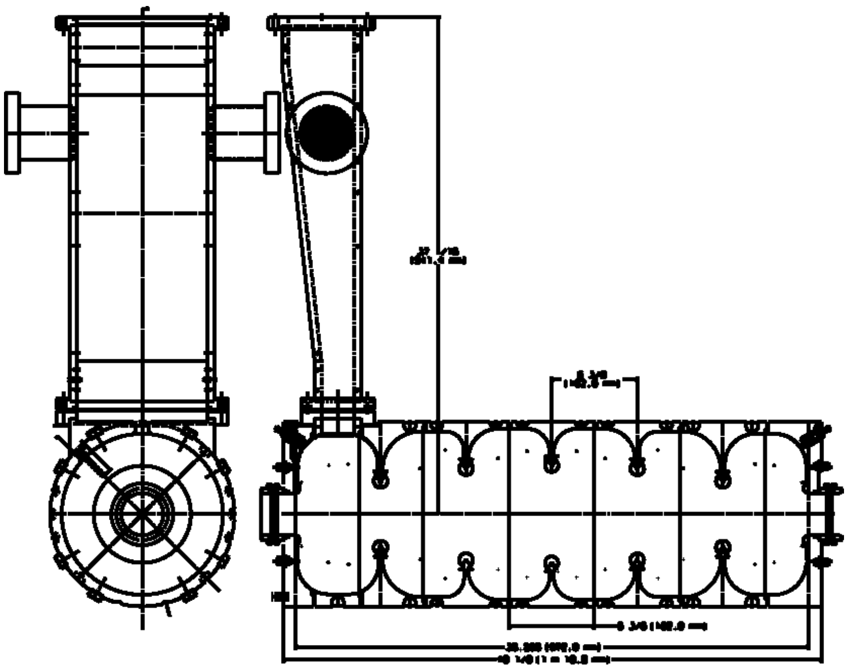
FY02 plans

805 MHz open cell cavity
- Keep running in Lab G to study effect of magnetic field

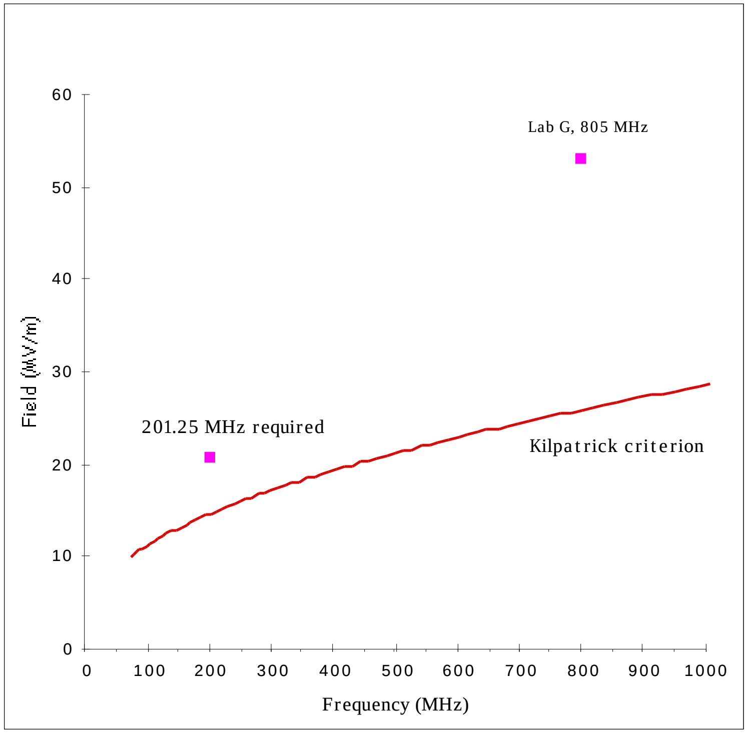
805 MHz closed cavity
- Run in Lab G to test gradient, foils, multipactor, breakdown, w/wo magnetic fields

201.25 MHz cavity
- begin mechanical tests for fabrication
  - e-beam welding
  - spinning
  - component development
  - Be foils, Al tubes

NCRF R&D Program and Plans



805 MHz open cell cavity tested in Lab G



Gradient achieved

53 MV/m surface field achieved at 13 MW (23.5 MV/m on axis).

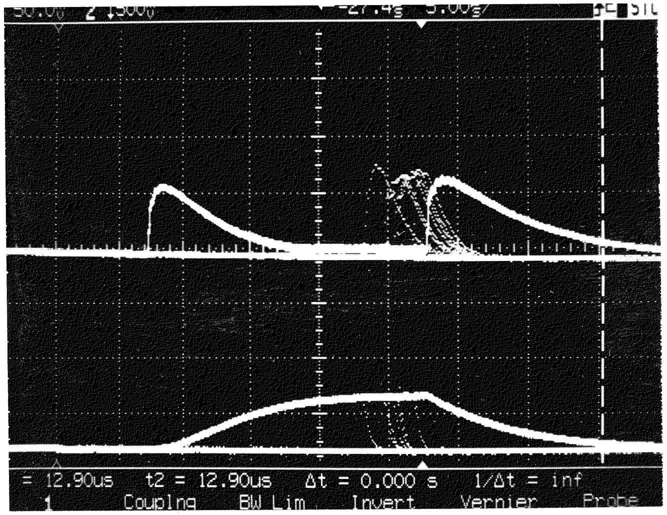
Magnet quench moved the cavity off axis.

Conditioning with magnetic field led to puncture of Ti Foil.

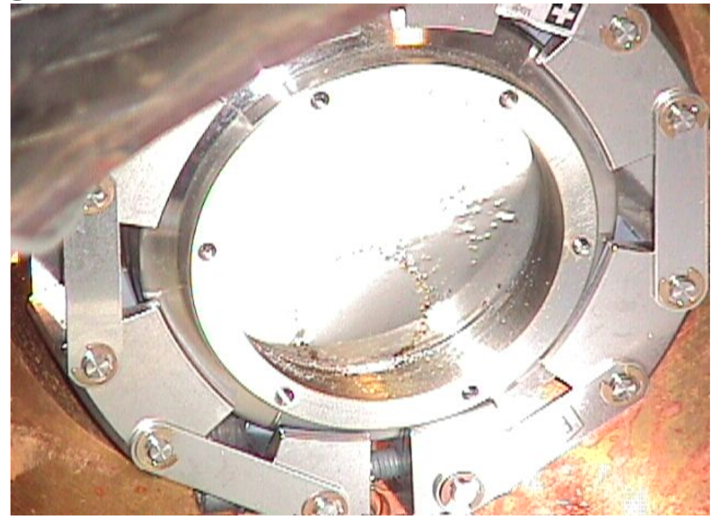
Inspection revealed evidence of concentrated arcing.

Strong dark currents and X-rays.

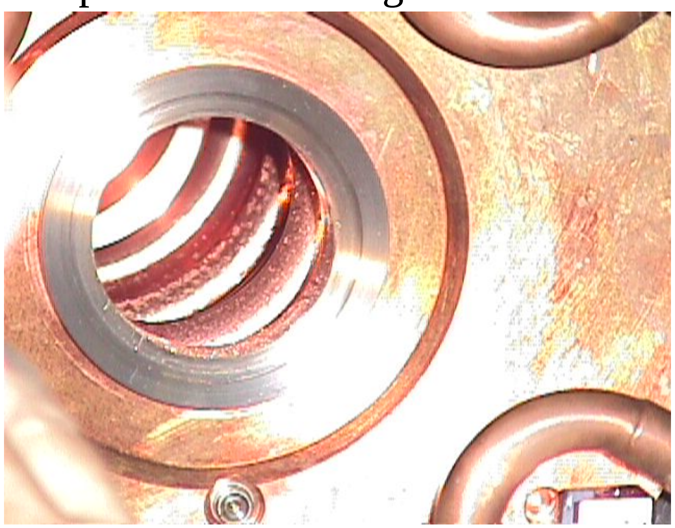
NCRF R&D Program and Plans



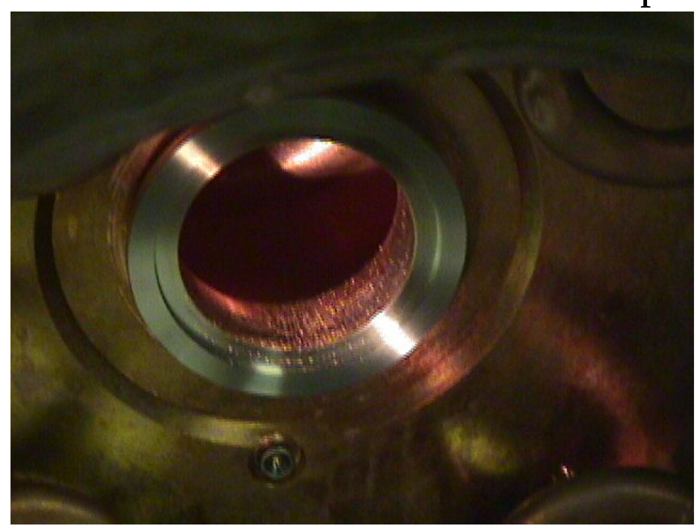
Scope trace showing breakdown events



Outside view of the west window sparks.

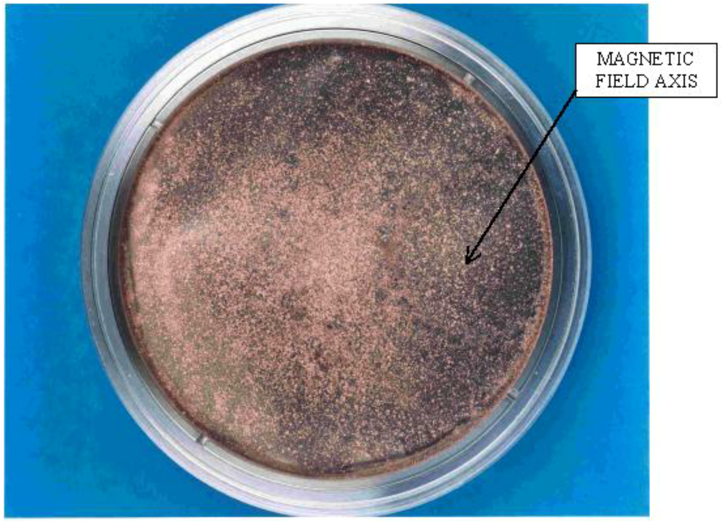


Iris spark damage.

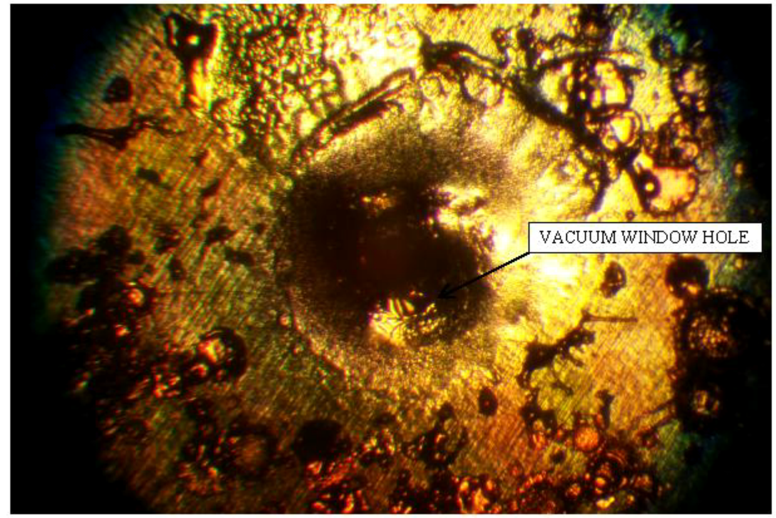


Copper grains left inside iris

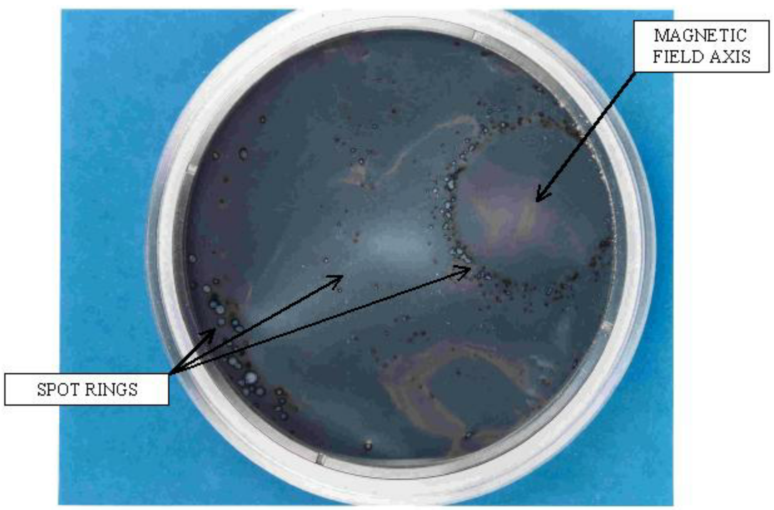
NCRF R&D Program and Plans



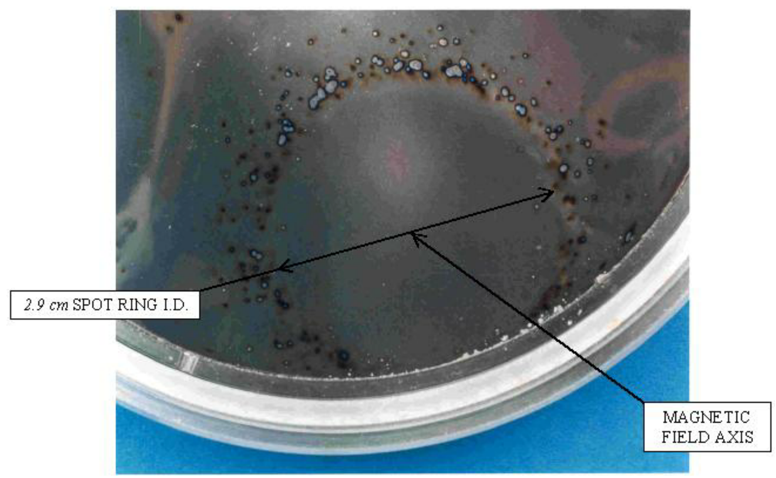
Ti Window vacuum side



100µm hole with copper particles

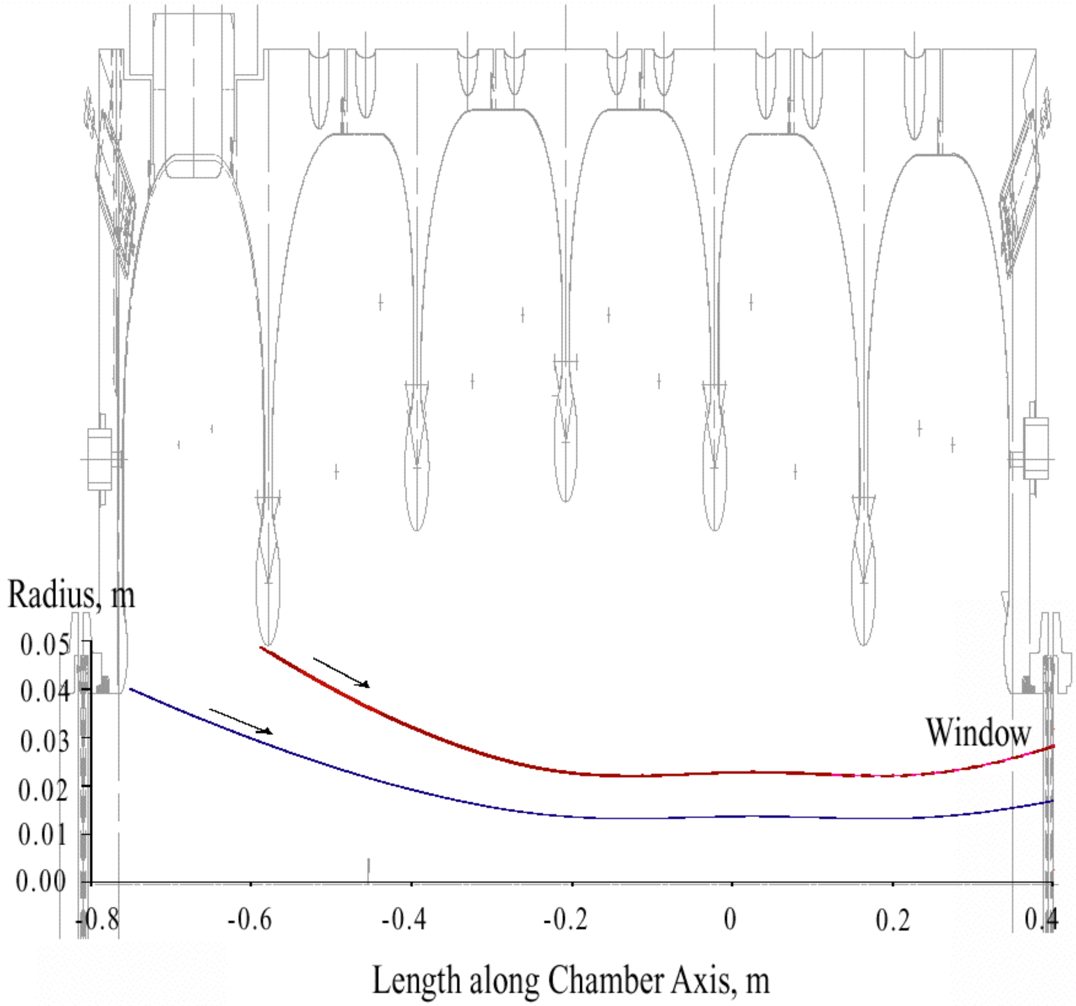


Air side with spot rings

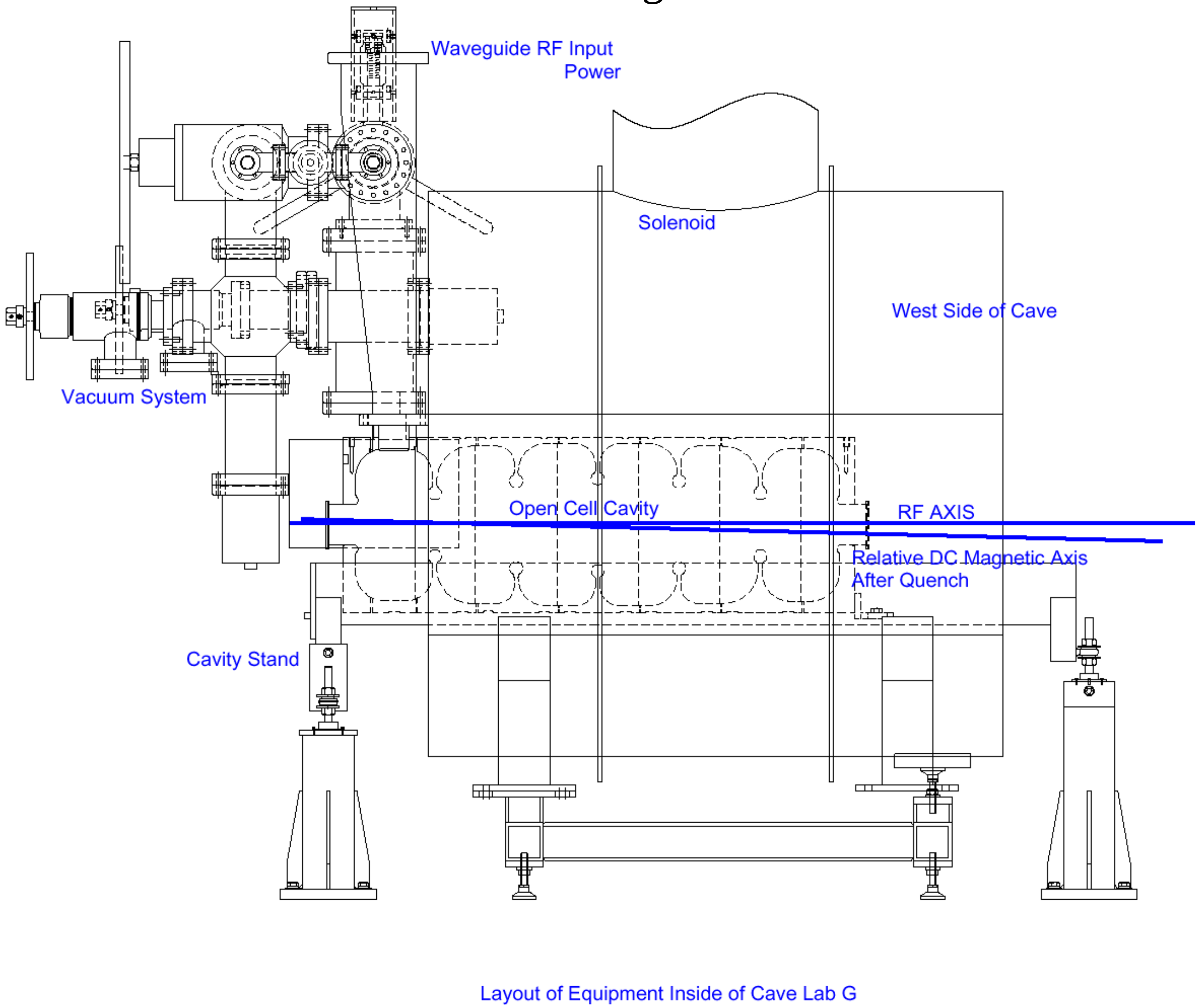


Close up of small ring

NCRF R&D Program and Plans

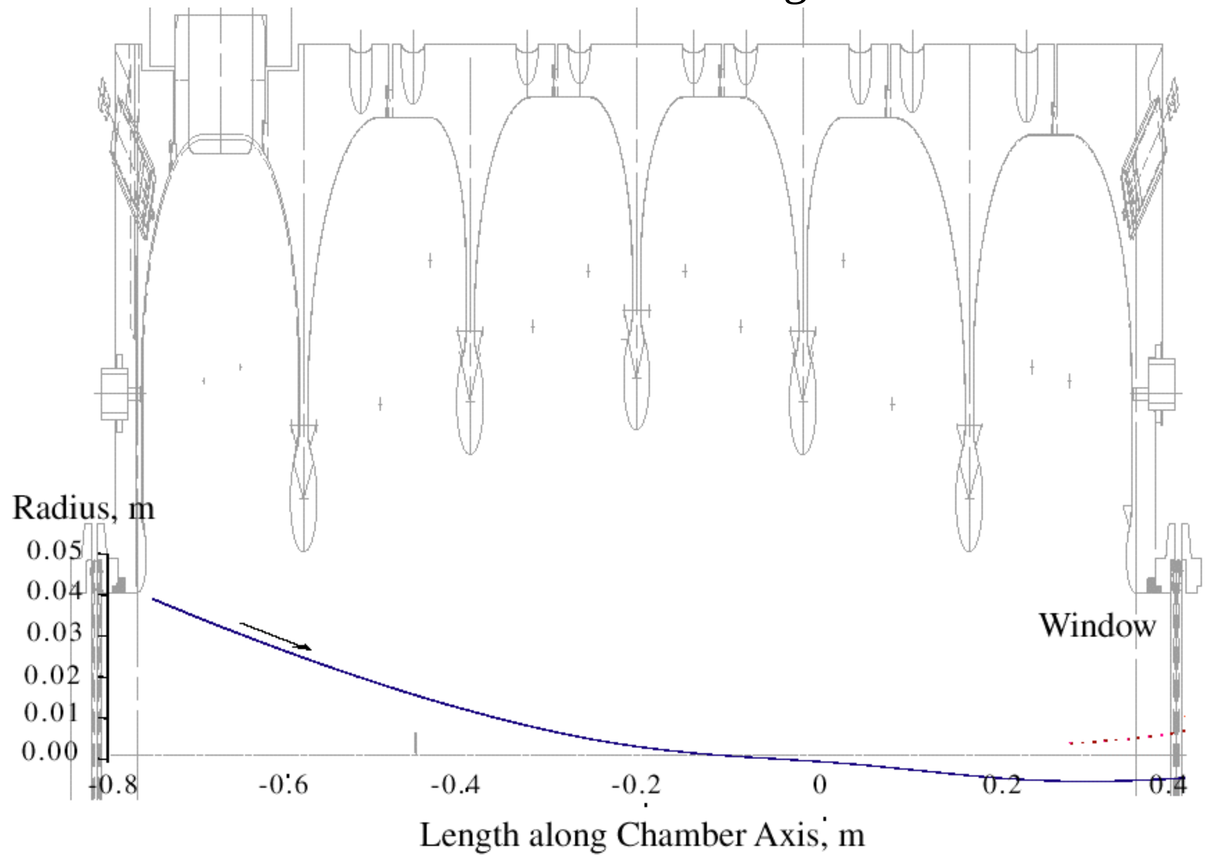


Pattern could be due to ions following magnetic field lines to the foil. (calc. circle diameter ~3.3 cm, meas. 2.9 cm). Tracking studies under way.



Cavity in solenoid, illustrating relative tilt after magnet quench

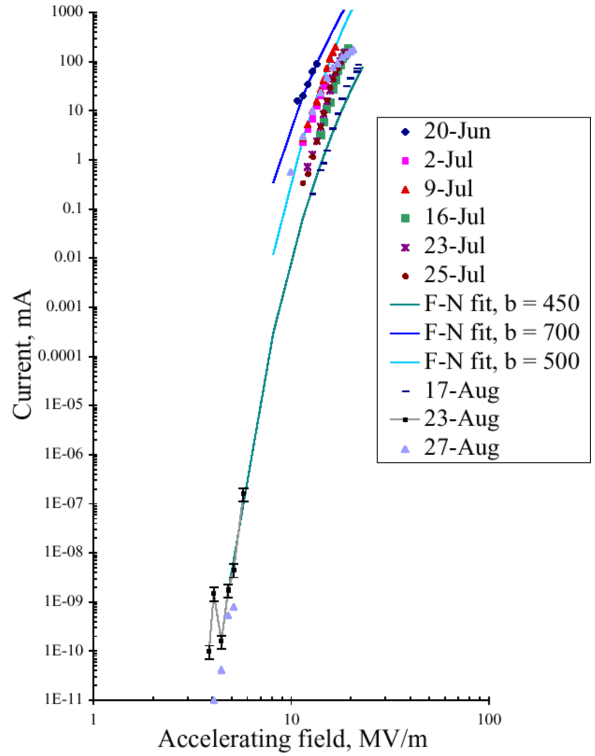
NCRF R&D Program and Plans



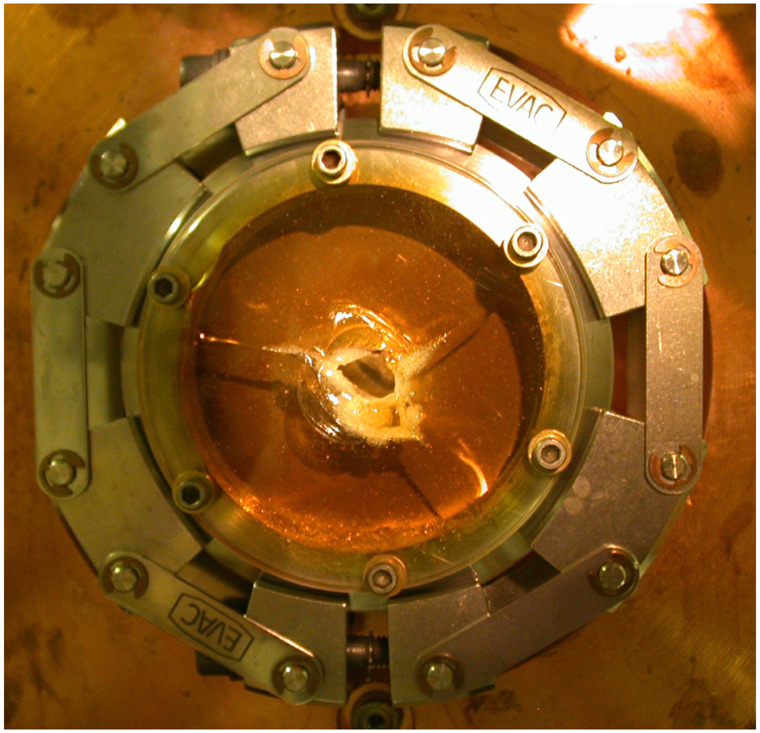
Trajectory of ions following tilted magnetic field lines to the foil

Circle offset consistent with magnetic field tilt

Dark current and X-rays



Dark Current vs. gradient



melted plexiglass cover

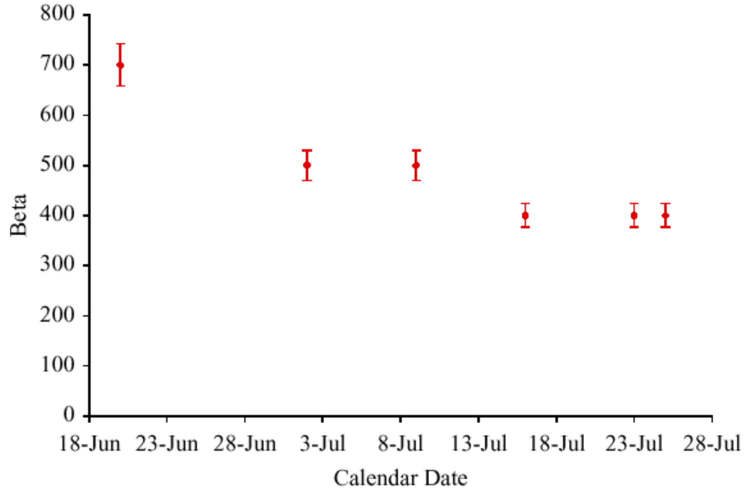
Up to 700 mA of dark current measured

Energy spectrum up to ~10 MeV (Beam Power <7 MW)

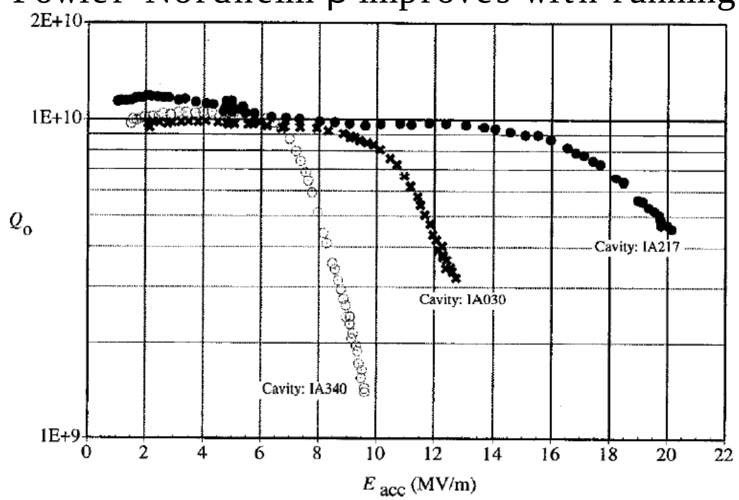
X-ray flux focussed in forward direction, more so with magnet on

Conditioning helps, but not enough? (6 orders of magnitude required?)

NCRF R&D Program and Plans

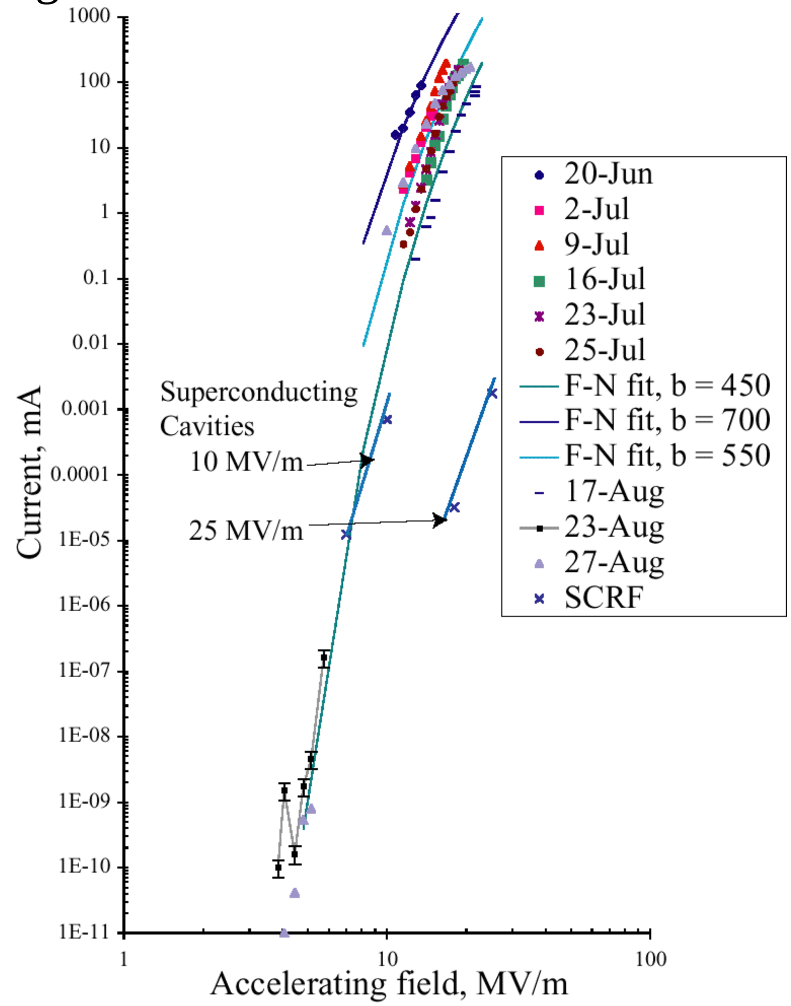


Fowler-Nordheim β improves with running



TJNAF 1.5 GHz SC cavity performance

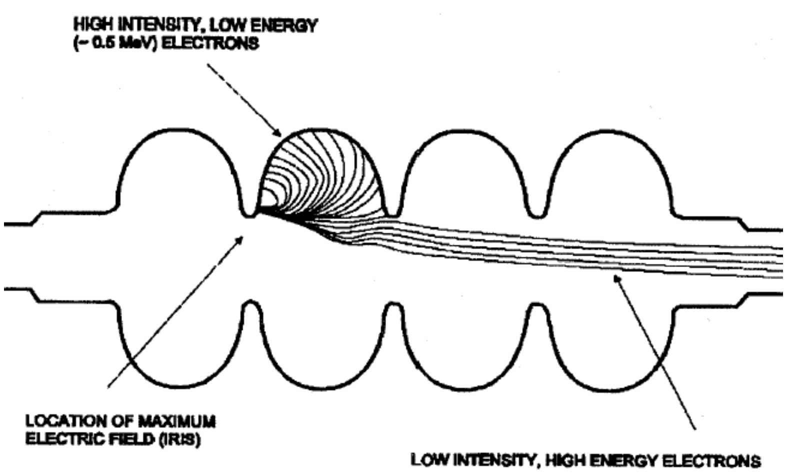
(Padamsee, Knobloch and Hayes, Fig 12.1.)



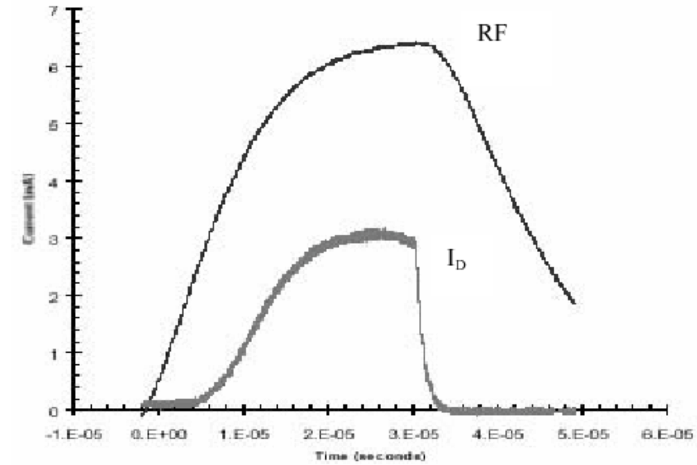
SCRF field emission is consistent with Lab G measurements.

elimination of particulates may yield many orders of magnitude improvement!

NCRF R&D Program and Plans

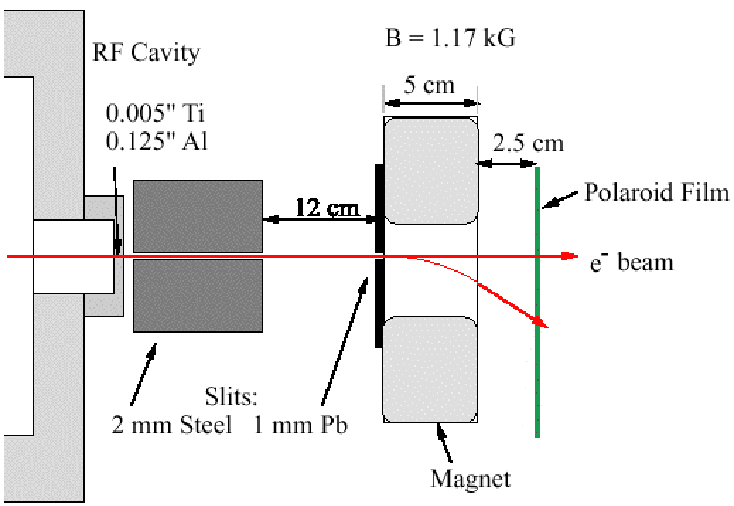


Example of field emission without magnet

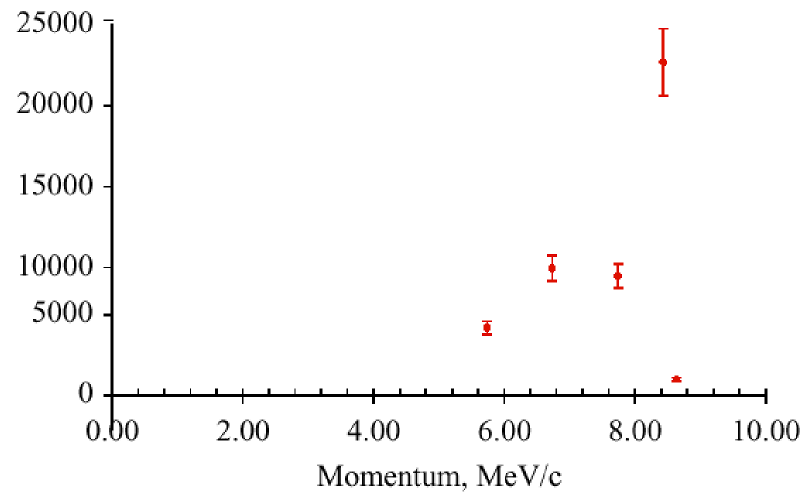


Dark current saturates (space charge limit?)

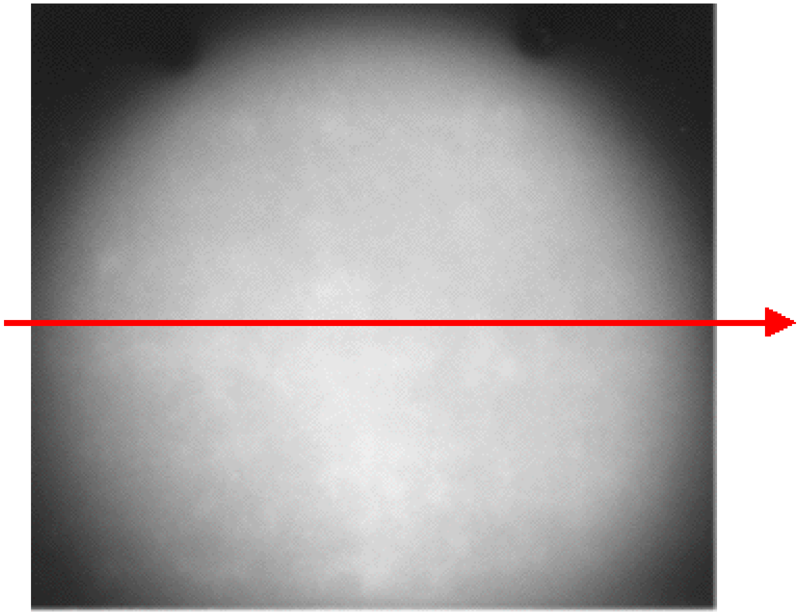
Small Gap, Permanent Magnet Dipole



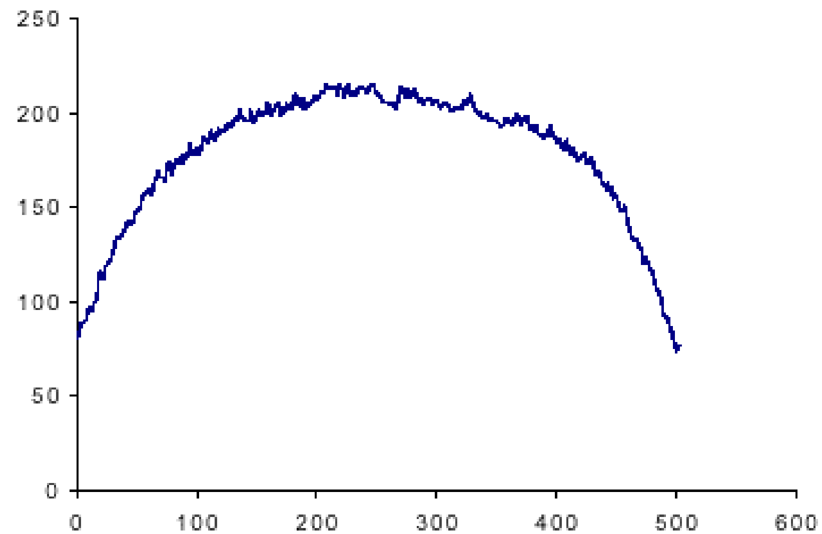
Dark current spectrometer in Lab G



Max. energy suggests accel. over many cells



Polaroid image in front of window

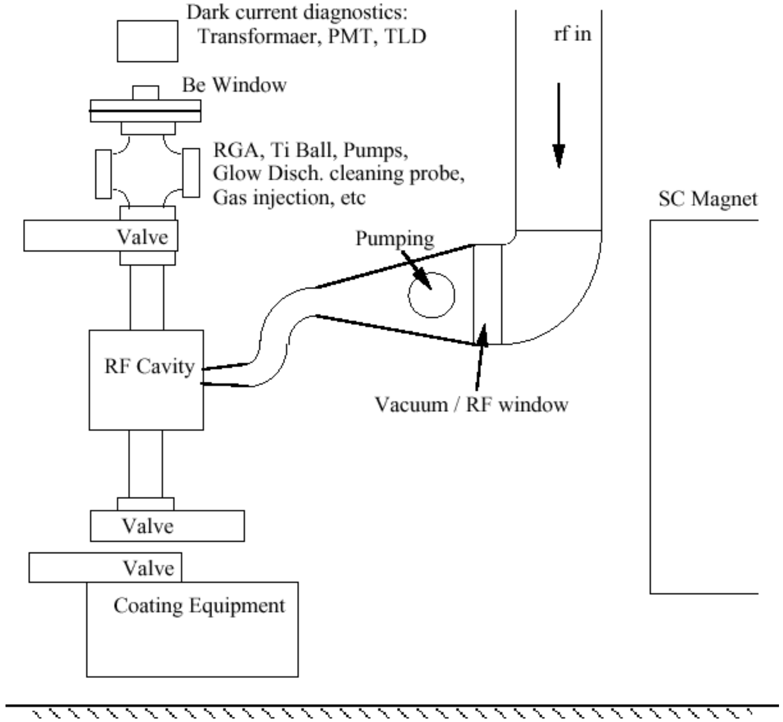


Smooth distribution seen with magnet off

More focussed with magnet on?

Scintilator just installed for real time diagnostics.

NCRF R&D Program and Plans



Possible coating test facility

- Facilities for in situ cleaning, coating or chemistry.
- Diagnostics for outgassing, X-rays and dark current.
- Could test in Lab G next to magnet.

Seeking input from world experts!

Candidate coating materials

Ti Should be smooth and pump gasses

TiN Lowers secondary emission coefficient

CaF2 Shown to lower dark current

Cu Need a smooth, clean coating

Ag Smooth, good elect. and therm. properties.

Au No oxide, otherwise like silver

diamond Best insulator? Bad secondary emission

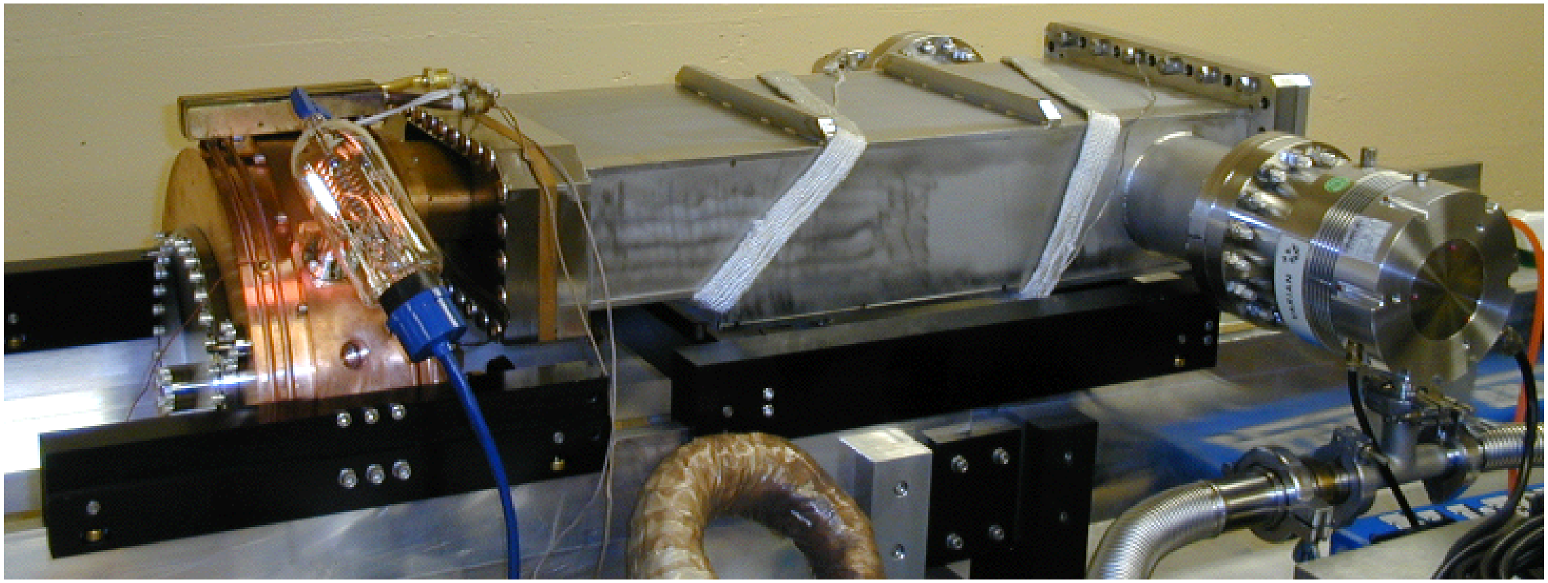
Coating methods

- **Sublimation** is probably the simplest, but works over line of sight.
- **Precipitation** from solutions requires a cavity geometry that can be drained when the process is finished.
- **Sputtering**, **CVD** etc. require somewhat more effort.
- **Electrodeposition**

Cleanliness may help a lot!

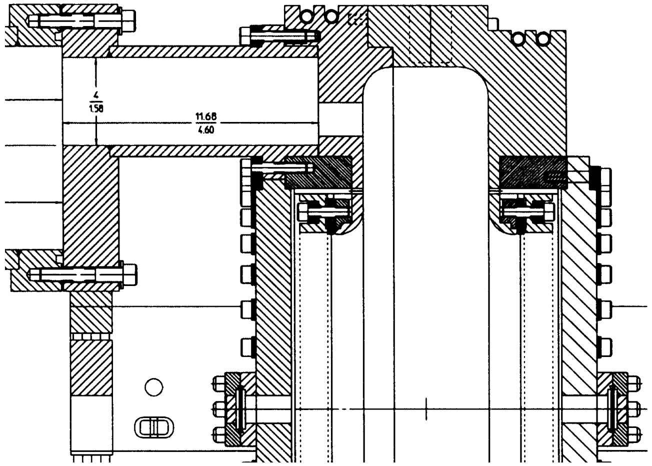
(c.f. superconducting RF)

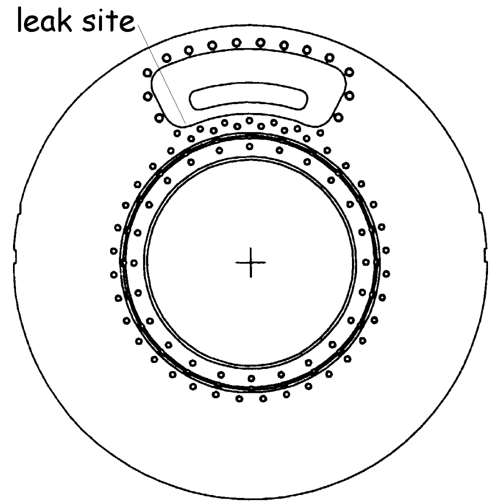
805 MHz single-cell cavity

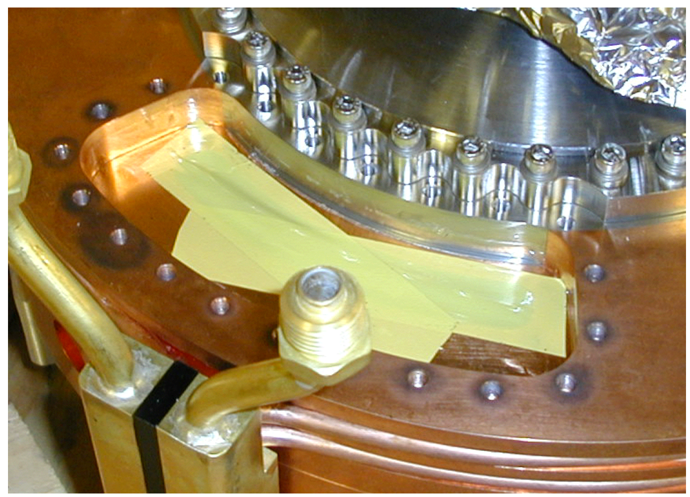


- Cavity fabrication was on schedule for testing in Lab G in FY01.
- Several thicknesses of Be foils have been procured.
- Leak detected in braze joint in an awkward place during final assembly.
- Repeated attempts to seal the leak have been unsuccessful.
- Now trying to install guard vacuum, test if base pressure is acceptable.
  If so RF testing can begin soon :)
  If not major rework will be required :(– May need reserve funds

NCRF R&D Program and Plans







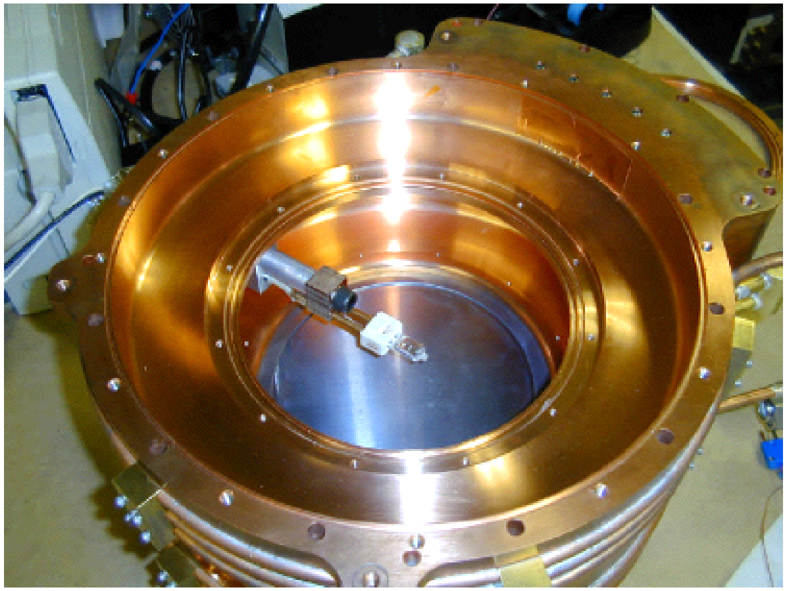
Geometry of coupler region. Leak is between copper and Stainless steel at the bottom of the recess. (Slot was cut after leak-checking at vendor).

Be Foil R&D

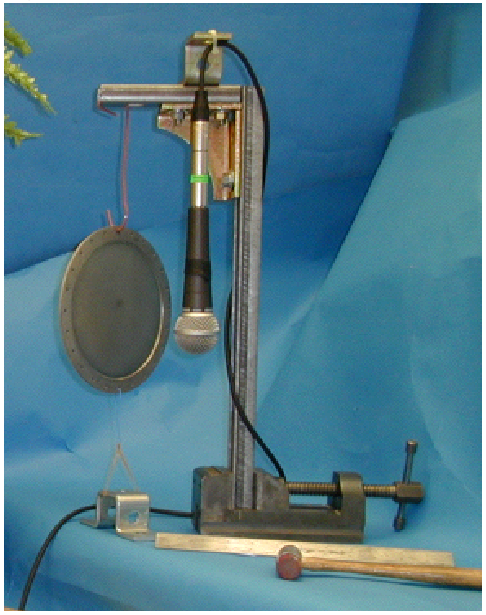
Various tests have been performed on the Be foils to measure pre-stress

- Halogen lamp tests repeated on new foils
- Acoustic tests at LLNL with accelerometer on foil
- Acoustic tests at LBNL with microphone

(Two foils from Brush-Wellman that failed in brazing were also tested)



Halogen lamp test

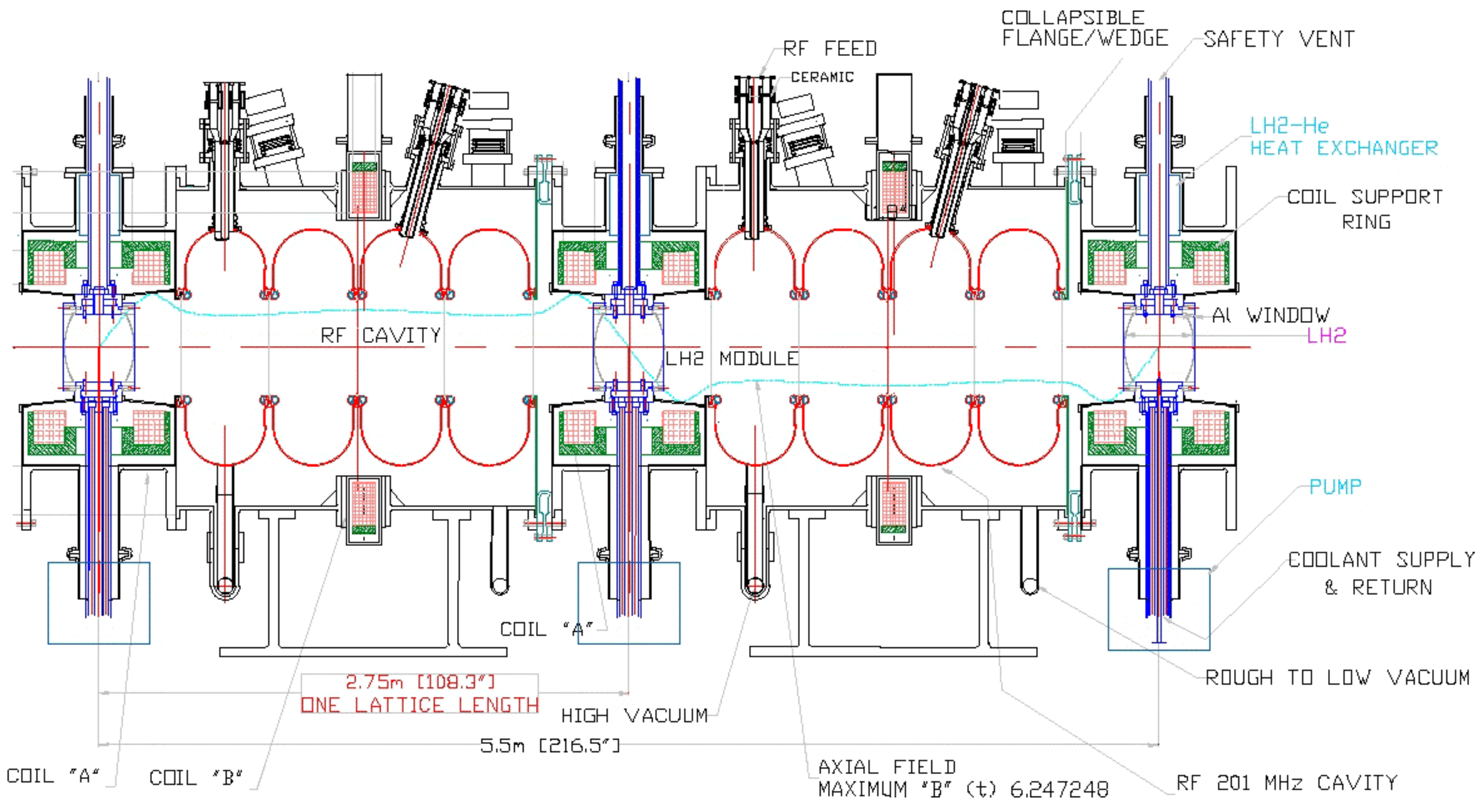


acoustic test

work in progress to turn these numbers into pre-stress

NCRF R&D Program and Plans

201.25 MHz cavity



Section of study-II cooling channel including 201.25 MHz cavities (proposed as a possible configuration for IMICE)

NCRF R&D Program and Plans

Conceptual design in study-II has beed developed further.

Dimensions modified slightly for mechanical clearance (tuner etc.).

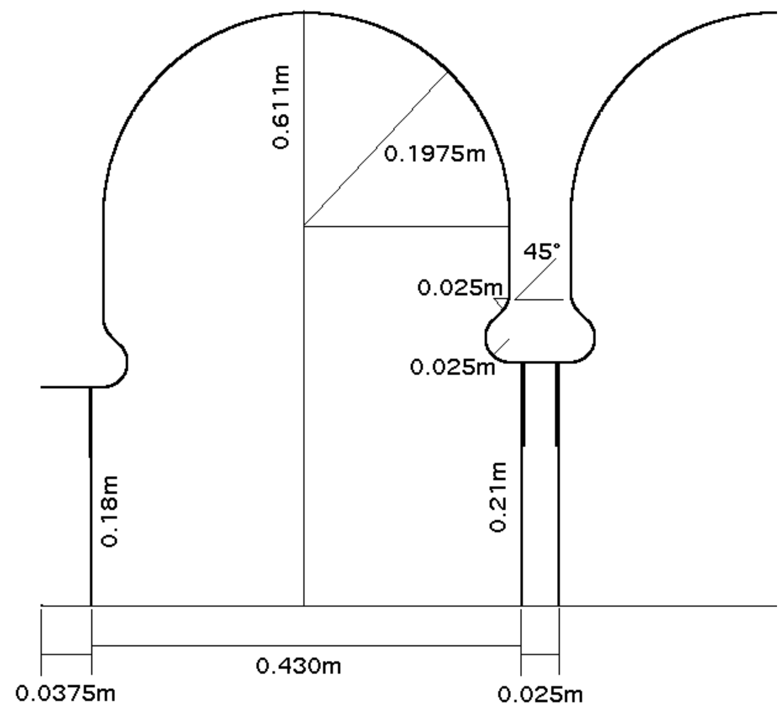
Focus now on first **high-power test model.** Two year fabrication plan before testing in **Linac Test Area** at FNAL.

FY02: e-beam welding deveolpment, spinning, tuner design, foil and grid development, fabrication of parts.

FY03: assembly of body, tuner fabrication, purchase RF window, foils &/or grids.

First cavity can be tested with foils or grids.

First cavity should be suitable for use in **IMICE** experiment.



IMICE cavity, modified from study-II

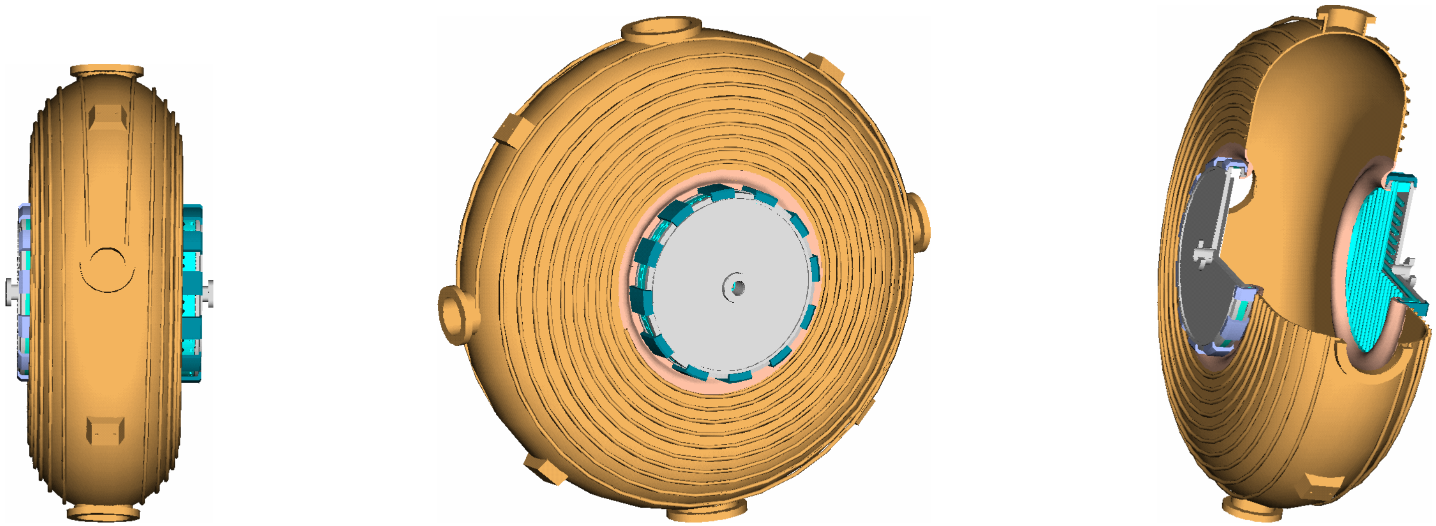
RF Parameters for 201.25 MHz IMICE

Table 1. Ideal Pillbox cavities for IMICE

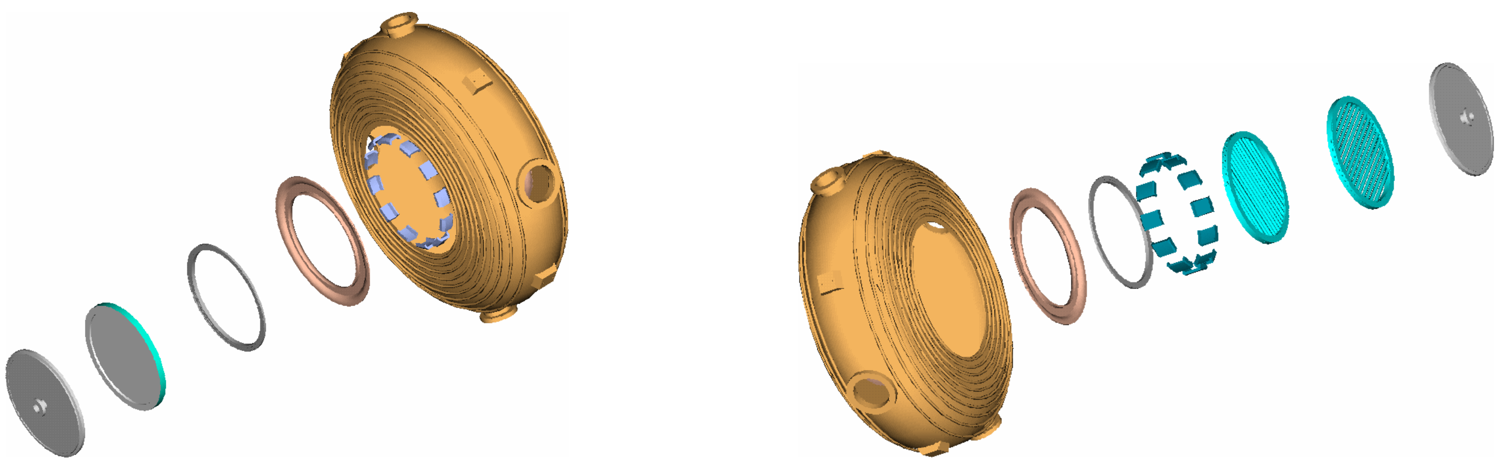
	2.75m cell	1.65m cell
Pillbox E_o (= E_{pk} on surface)	**15.48 MV/m**	**16.72 MV/m**
Length, L	**0.466 m**	**0.559 m**
Transit time factor, T	0.798	0.718
V_{eff} (on crest, on axis)	5.76 MV	6.71 MV
Est. loss per absorber	~12 MeV	~7 MV
Est. loss in Be foils (cent,edge)	0.75 (1.48) MeV	0.42 (0.84)MeV
Number of cavities, n	4	2
Total energy loss per cell	12.75 (13.5) MeV	7.42 (7.84) MeV
Req. energy gain per cavity	3.19 (3.38) MV	3.71 (3.92) MV
Approximate phase angle, Θ	33.6-35.9°	33.6-35.7°
Peak power per cavity	3.646 MW	4.635 MW
Forward power (3τ filling)	4.038 MW	5.134 MW
Total per cooling cell	16.15 MW	10.27 MW

Table 2. Omega shaped cavities for IMICE

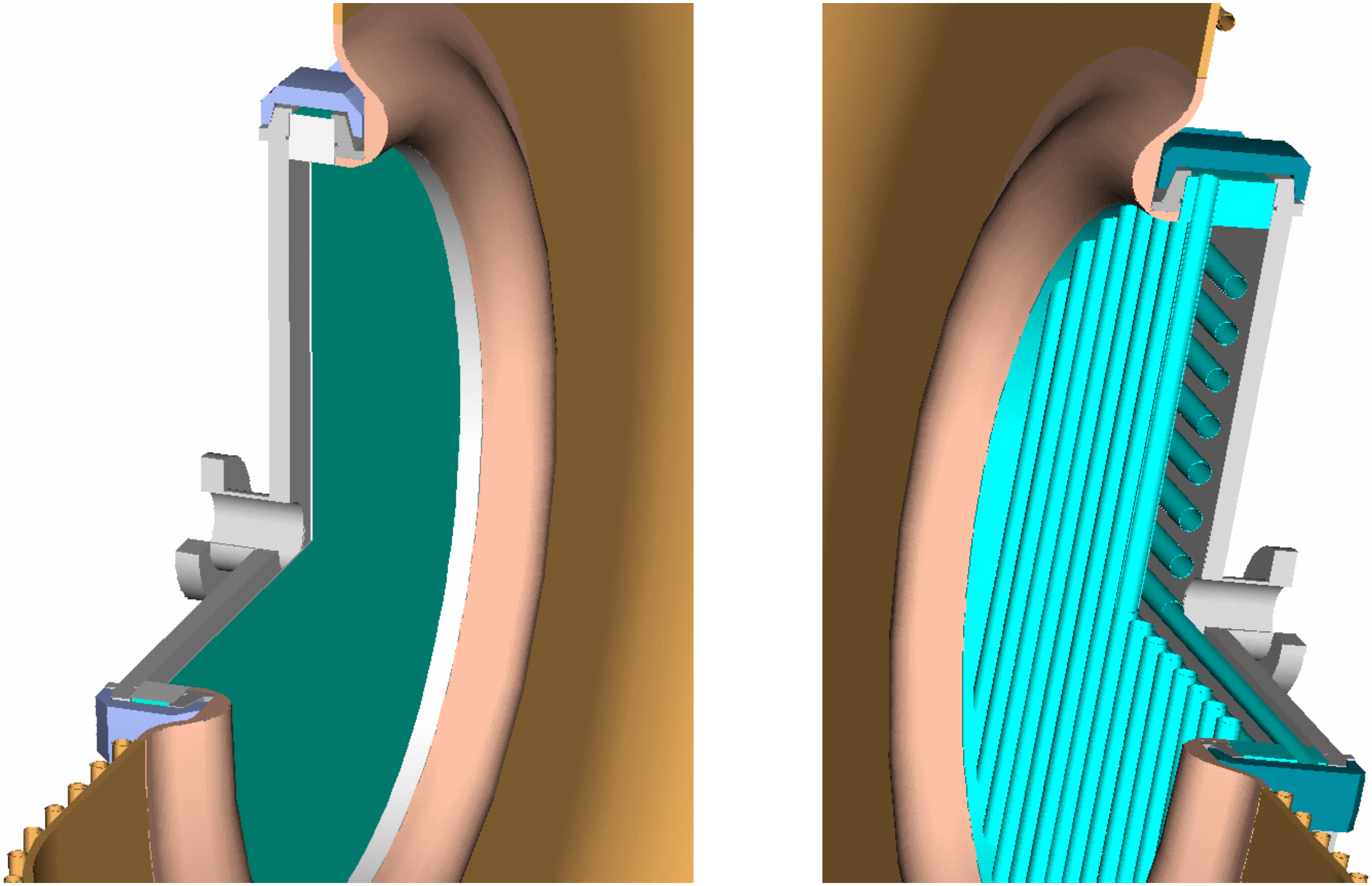
V_{eff} (on crest)	**5.76 MV**	**6.71 MV**
Length	0.405 m (T=0.845)	0.483 m (T=0.784)
$E_o$equivalent	16.83 MV/m	17.72 MV/m
E_{pk} on surface	20.62 MV/m	23.06 MV
Peak power per cavity	3.818 MW	4.491 MW
Forward power (3τ filling)	4.228 MW	4.974MW
Total per cooling cell	16.91 MW	9.95 MW



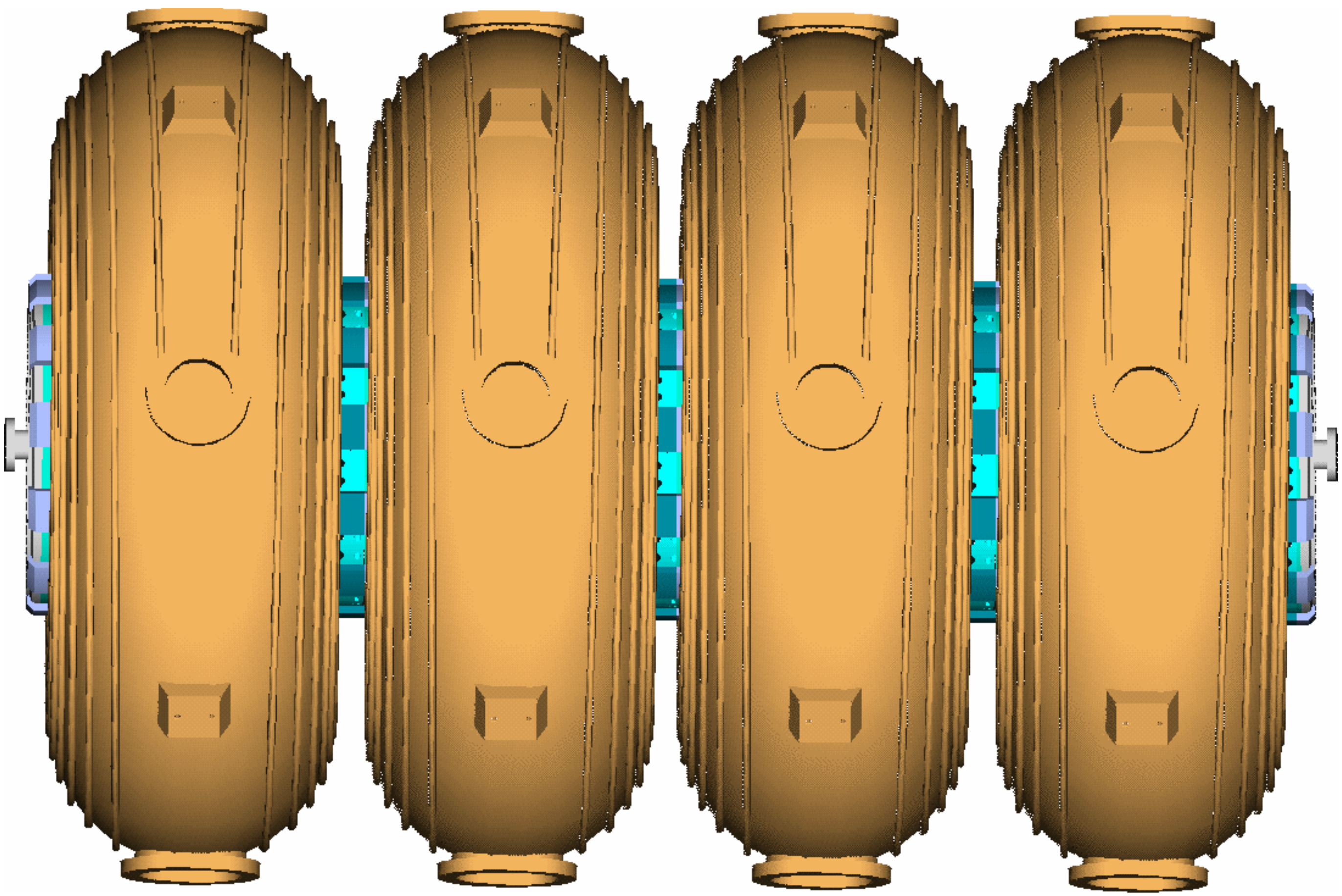
201.25 MHz cavity conceptual design



Exploded views showing foil and grid mounting hardware



detail views of foil and grid mounting assemblies



This design can form the basis of the IMICE channel

Conclusions

- Lab G operations have been very valuable in the study of surface field, dark currents, X-ray flux, breakdown and conditioning and effects of strong magnetic fields on all of the above.
- Single-cell 805 MHz cavity will continue this work, including the effects of Be foils of different thicknesses, surface coatings, etc.
- 201.25 MHz cavity conceptual design is complete. Detailed design work continues.

FY02 plans

- 805 MHz open cell cavity

  Keep running in Lab G to study effect of magnetic field.
- 805 MHz closed cavity

  Run in Lab G to test gradient, foils, multipactor, breakdown, w/wo magnetic fields.
- 201.25 MHz cavity

  Finish detailed design, begin mechanical tests for fabrication, e-beam welding, spinning, tuner design, foils/grids etc.